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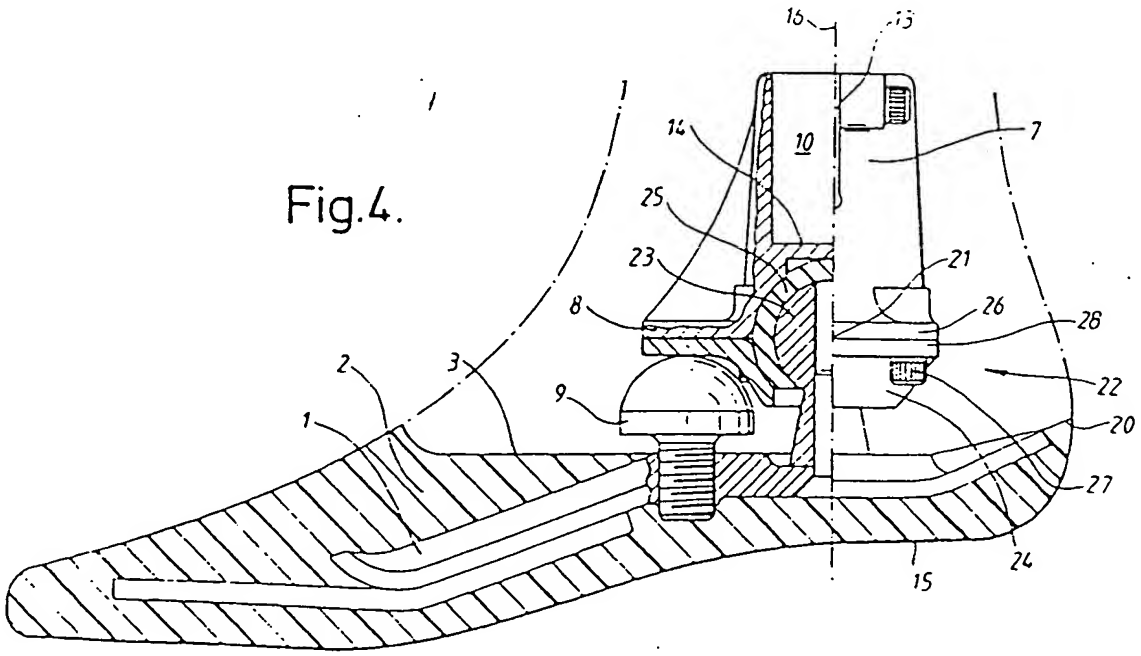
(54) Improvements in artificial limbs

(57) A method of making an artificial leg includes the step of selecting a foot assembly from a range of foot assemblies each of a different kind but each having a like connecting member (7). In each foot assembly the connecting member has a mating surface (14) defining a receptacle (10) which engages a corresponding surface on a shin member, e.g. a shin tube, and which is in a defined position within the foot assembly so that the foot assemblies are all interchangeable. The shin member can be clamped into position in receptacle (10) by tightening a screw across a slot (13). The prosthetist is therefore able to detach one foot assembly from a patient's artificial leg and replace it with another of a different kind without altering the length of the shin member for that particular patient.

Fig.4.



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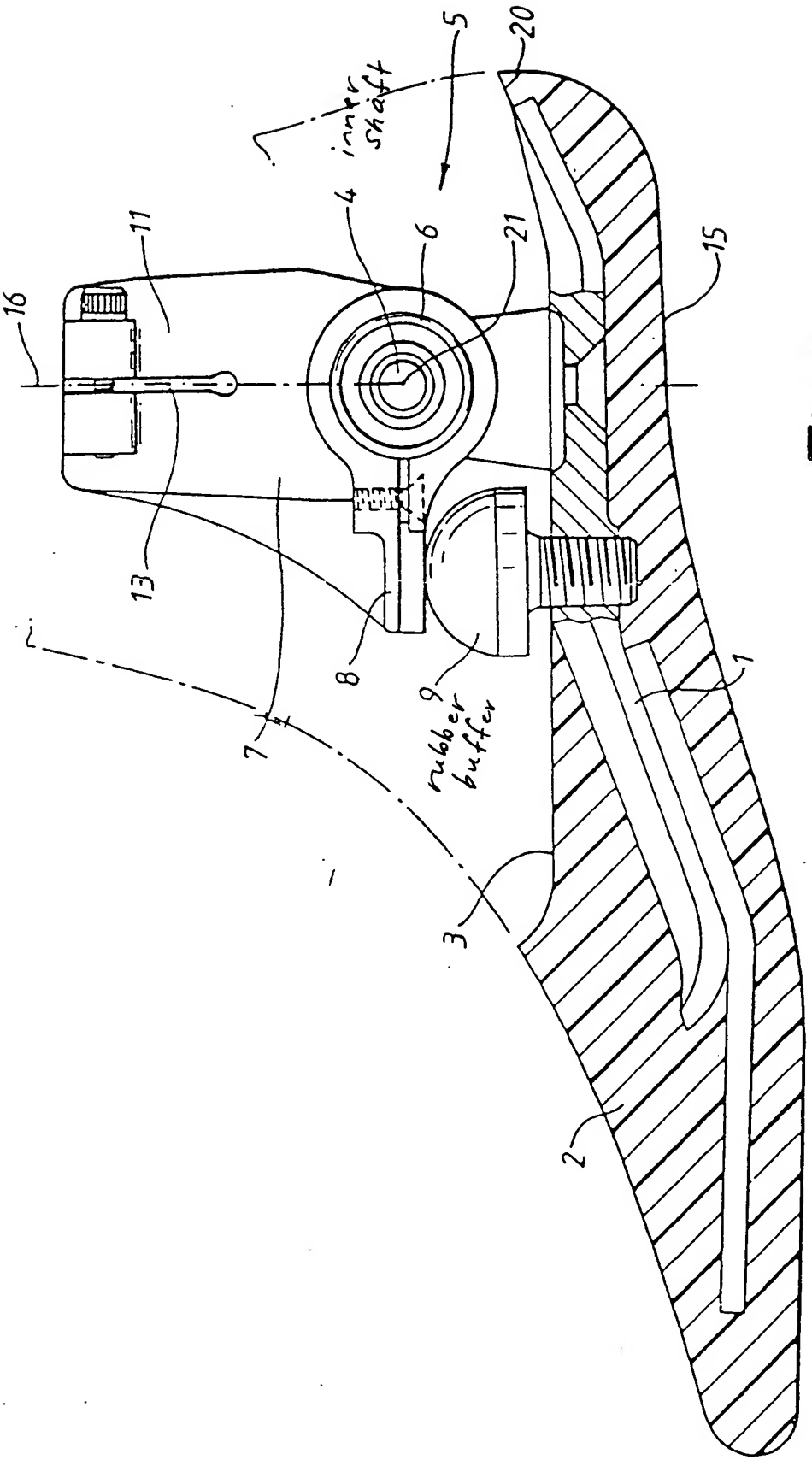


Fig.1.

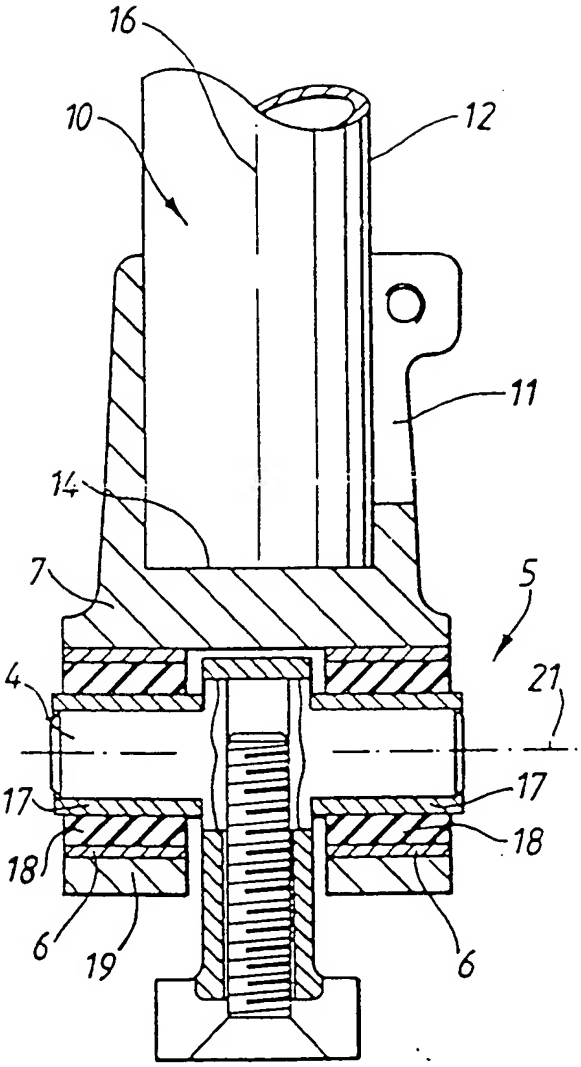


Fig.2.

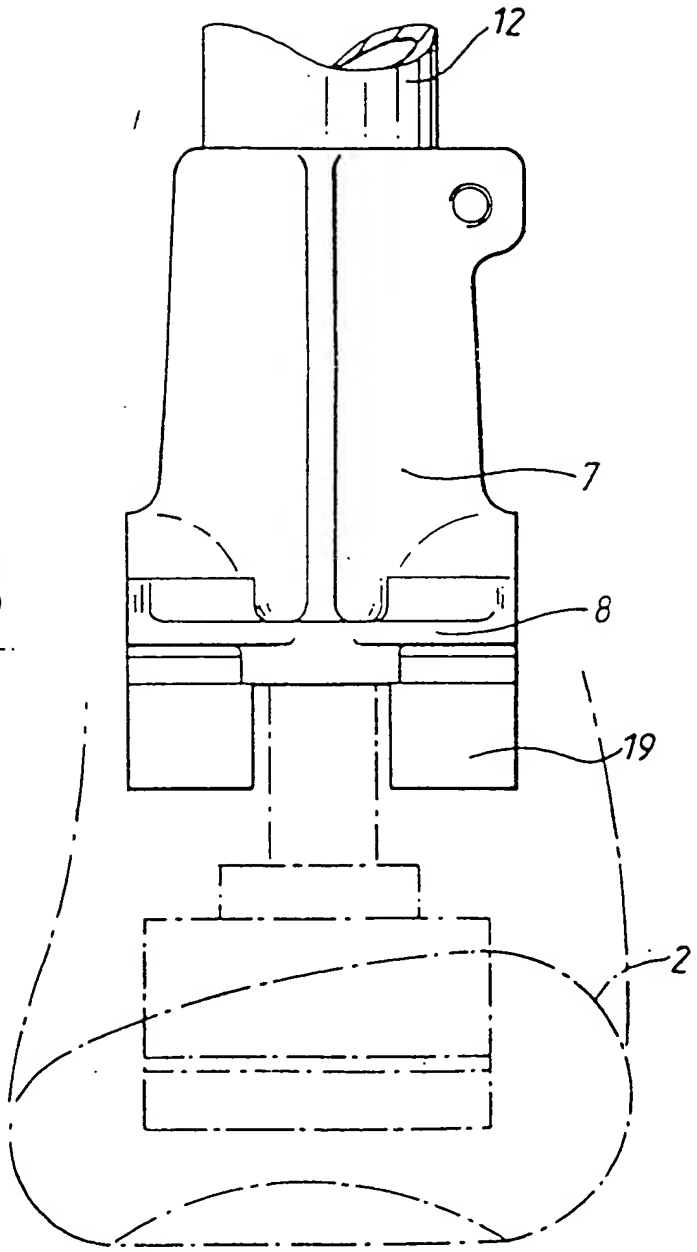


Fig.3.

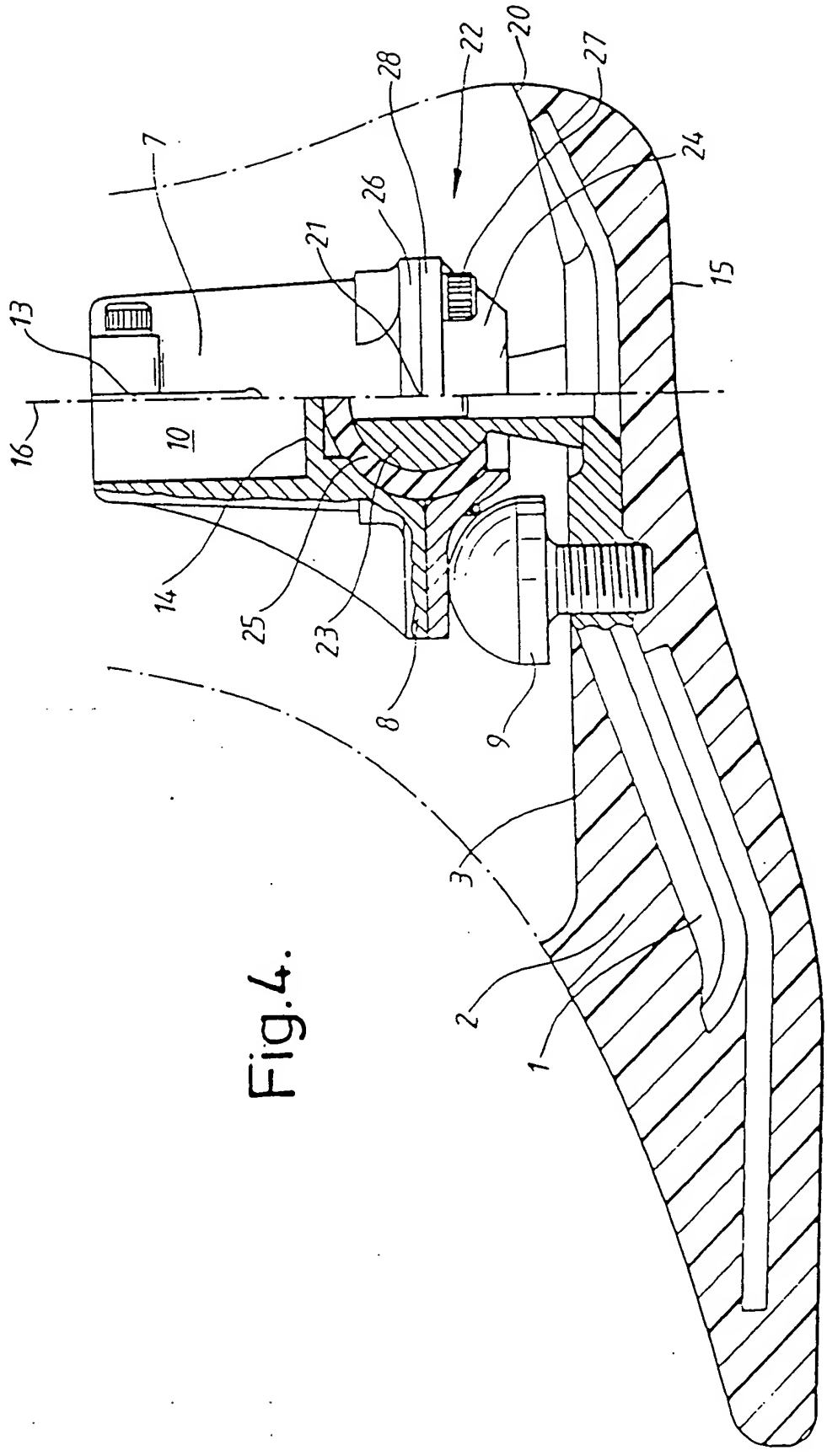


Fig.4.

Fig.5.

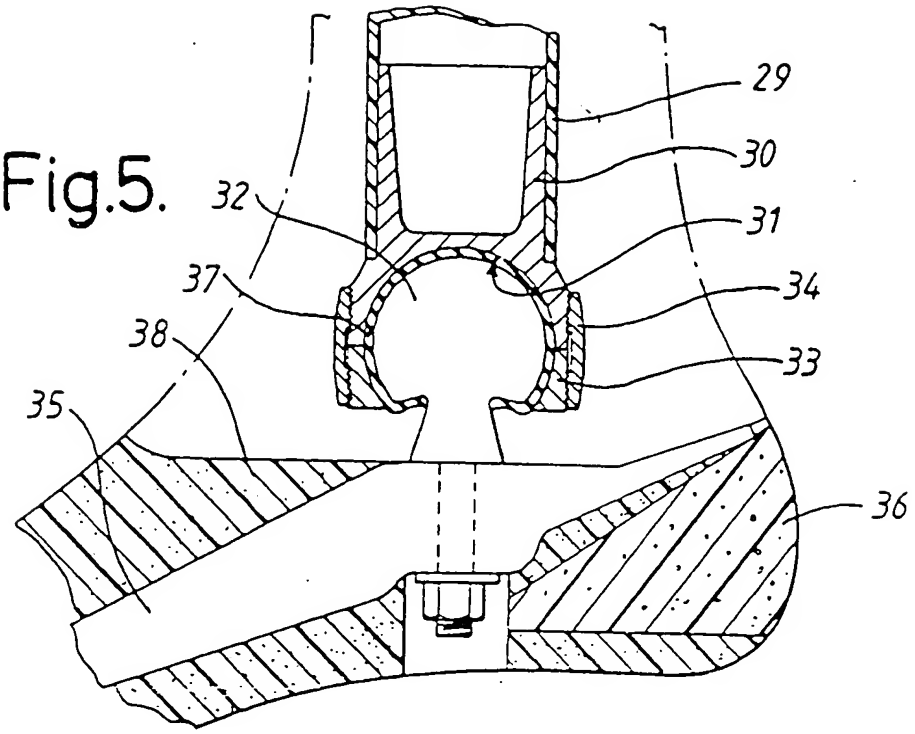
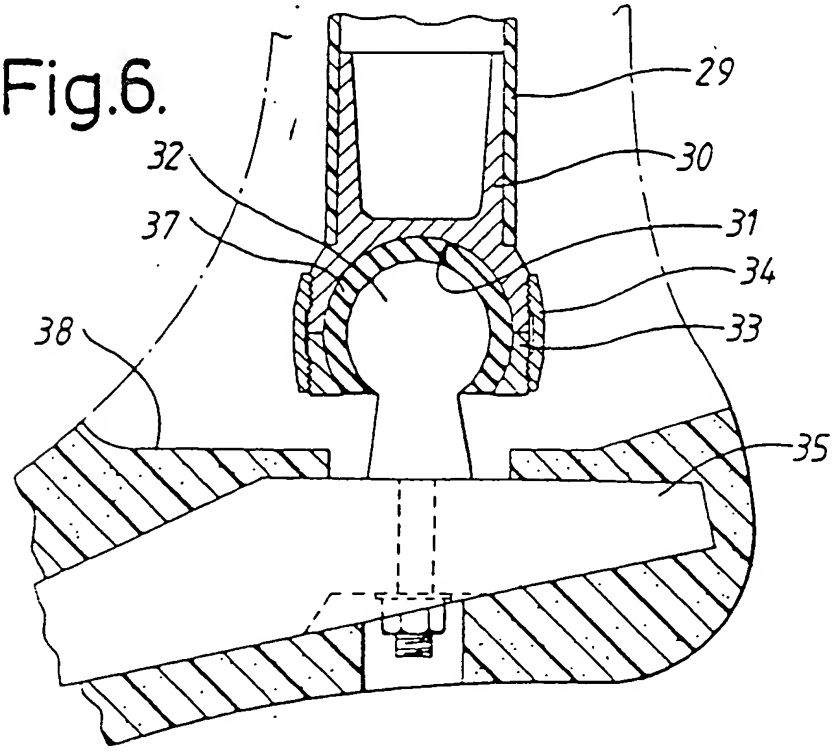


Fig.6.



SPECIFICATION
Improvements in artificial limbs

This invention relates to a method of making an artificial leg, and in particular to the connection of an artificial foot to an artificial shin.

The required characteristics of a foot and ankle of an artificial leg vary from one patient to another, depending on for example the strength of the patient. It is therefore desirable that various alternative artificial foot assemblies can be attached to the artificial shin at the fitting stage to determine which foot assembly is most suitable.

According to one aspect of the invention, a method of making an artificial leg comprises the steps of: (i) providing a shin member of a required length having a lower end portion including a mating surface; (ii) providing a plurality of interchangeable artificial foot assemblies each of a different kind and each including a connecting member constructed to fit the lower end portion of the shin member and to be removably connected thereto by releasable fastening means, the connecting member including a mating surface for engaging the shin member mating surface so as to determine the position of the connecting member relative to the shin member; (iii) selecting any one of the foot assemblies, the selection being independent of the shin member length; and (iv) mounting the selected foot assembly on the lower end portion of the shin member and securing the foot assembly to the latter by the releasable fastening means. This method enables the artificial limb fitter to try various foot assemblies on a patient without necessarily having to change other components of the limb such as the shin or having to alter adjustments already carried out on the rest of the limb. The method can therefore reduce the total setting-up time. By providing a range of interchangeable foot assemblies, the requirements of most patients can be met, from the most active to those of extremely limited activity.

Also of advantage is the ability to replace the foot assembly on a limb which a patient may have been wearing for a prolonged period without changing settings to which the patient has adapted and has become accustomed. With known artificial limb components, if a patient has for example developed other infirmities since the limb was fitted, it has been necessary to make modifications to the limb as a whole as a result of having changed the foot assembly.

Since the invention enables the foot assembly to be replaced without altering the shin tube length, a particular saving in effort and time is gained with an artificial shin which is not the normal light alloy tube, but is for example a composite structure or other lightweight component, these latter types of shin being more inconvenient and difficult to replace than the relatively simple tube.

The connecting member of the foot assembly may be adjustably mounted on the foot so that the fitter, when carrying out the method of the invention, may additionally adjust the heel height either before or after fitting the foot assembly to the limb. Specifically, the adjustment may involve setting the angle of the foot relative to the shin axis as defined by the connecting member by rotating the foot above the transverse horizontal axis. This setting is not disturbed when the foot assembly is mounted on or removed from the shin. Thus, if each of the plurality of foot assemblies is set to a given heel height, the fitter may interchange foot assemblies on the limb in the knowledge that the crotch-to-ground distance for the limb will remain substantially constant from one foot assembly to another.

The fastening means for connecting the foot assembly to the shin may be a screw operated clamp forming part of the connecting member, and in the case of a tubular shin, the clamp may be internal or external relative to the tube. With the tubular shin and an external clamp, the mating surfaces may be respectively the end of the tube and the base of a corresponding cylindrical receptable in the connecting member. Alternatively, in the case of a composite shin piece which is bonded to a lower shin component, the mating surface may be the inner surface of a concave spherical recess which engages a spherical ball member common to each different foot assembly. Fastening means in the form of a turnbuckle ring may be used to trap the ball member in the recess.

One or more of the foot assemblies may include a resilient ankle joint allowing movement between the connecting member and the foot. Uniaxial ankle joints are well known, and on common construction that has been used for some considerable time includes a rotating bearing with a transverse horizontal axis, and rubber cushions or buffers between the connecting member and the foot to limit the degree of ankle flexion. The buffers are positioned in front of and to the rear of the joint axis, and have different spring rates to provide a differential flexion resistance, the resistance to dorsi flexion usually being higher than the resistance to plantar flexion. This construction has a disadvantage in that it is difficult to make a neat cosmetic foam covering for the angle joint due to the amount of space taken up by the bearing and the rubber buffers. In particular, there is very limited space available for foam cosmesis behind the joint. Therefore according to another aspect of the invention, a limb prothesis comprises:— (i) a shin component; (ii) a foot assembly including (a) a foot and an upper ankle component, which component is adapted to connect the assembly to the shin component, the assembly including an ankle joint permitting plantar and dorsi flexion of the foot about an ankle joint axis, and (b) elastic coupling means between the foot and the upper ankle component to resist the said flexion, the elastic rate of the coupling means for dorsi flexion being different from its elastic rate for plantar flexion, the coupling means including one or more elastic members none of which have their major part to

the rear of the ankle joint axis; and (iii) a flexible cosmetic shin covering surrounding the shin component and at least the upper ankle component of the said assembly, which covering extends below the ankle joint axis and occupies the space between the upper ankle component and the foot. The ankle joint has flexible coupling elements which are either symmetrical about the axis or are in front of the axis so that sufficient space is available to the rear of the axis for a cosmetic foam covering. By eliminating the rear buffer of the known construction, the structural components of the limb in the region of the ankle can be made relatively compact, allowing the use of a relatively thick foam cosmetic covering which abuts neatly with a flexible foot moulding and maintains an acceptable external appearance when the ankle joint is flexed.

In two of the preferred embodiments described hereinafter resistance to flexion is provided by two rubber couplings, one of which is an integral part of a resilient, rubber filled bearing and resists rotation of the foot about the ankle joint axis equally for dorsi and plantar flexion, and the other coupling is a rubber buffer mounted on the foot in front of the joint axis acting against a forward projection of the upper ankle component to resist dorsi flexion. The front buffer is also preferably adjustably mounted so that the heel height can be set with neither rubber coupling exerting any bias to the joint, i.e. with the joint in its neutral position. Flexion of the ankle in either direction is resisted by a shear force in the resilient bearing. This type of elastic coupling has the advantage of a relatively predictable compliance characteristic over a relatively wide range of flexion compared with the known construction. It also allows a degree of flexibility both torsionally about the shin axis and longitudinally relative to the same axis, to improve the comfort of the limb for the patient.

The invention will now be described by way of example with reference to the drawings in which:—

Fig. 1 is a partly sectioned medial side view of a first foot assembly;

Fig. 2 is a sectioned front view of the ankle components of the first foot assembly;

Fig. 3 is a front view of the ankle components of Fig. 2;

Fig. 4 is a partly sectioned medial side view of a second foot assembly which is interchangeable with that of Fig. 1;

Fig. 5 is a partly sectioned medial side view of a SACH foot assembly with an alternative fastening means; and

Fig. 6 is a partly sectioned medial side view of part of a further foot assembly which is interchangeable with the foot assembly shown in Fig. 5.

In the following description two pairs of foot assembly embodiments are referred to, each pair illustrating a particular means of fastening a foot assembly to the shin and each showing two of several possible foot assemblies which can be used. The first embodiment, shown in Figs. 1 to 3, is a foot assembly having a flexible ankle joint allowing flexion about a single, substantially horizontal axis. The assembly comprises a foot keel 1 encased in a flexible foot moulding 2 having a generally horizontal upper surface 3. The keel is attached to the inner shaft 4 of a resilient bearing 5 whose outer shell 6 is clamped in a connecting member or upper ankle component 7. The ankle component has a forwardly extending projection 8 arranged to engage a front buffer 9 adjustably mounted in the keel 1. The ankle component 7 serves to fasten the foot assembly to a shin tube, and for this purpose it has a cylindrical receptacle 10 (see Fig. 2) with a slotted outer wall 11 so that the shin tube 12 can be clamped in the receptacle by tightening a screw across the slot 13. The receptacle end wall 14 constitutes a mating surface which engages the end of the shin tube 12 to define the position of the assembly relative to the tube. The position of the surface 14 relative to the sole 15 of the foot is a predetermined fixed distance, which distance is common to this and any other foot assembly intended to form part of the range of interchangeable foot assemblies.

Referring to Fig. 2, the resilient bearing has two sections, one to each side of the shin tube axis 16, and each section comprises an inner sleeve 17 bonded to a rubber sleeve 18 which is bonded in turn to the outer shell 6. The shaft 4 is fixed in the inner sleeve 17 and both bearing sections are clamped in the ankle component 7 by means of screws (not shown) which tighten the wall 19 of the component 7 around the outer shells 6. All flexion of the ankle is therefore taken up by the rubber sleeve 18, to produce shear deformation. This type of coupling enables a relatively large ankle flexion range to be obtained compared with conventional rubber buffers which are deformed by compression rather than shear, and in addition the compliance of the bearing is relatively predictable. These characteristics of the bearing make the foot assembly particularly suitable for patients of limited activity since the resistance to plantar flexion (i.e. anti-clockwise movement of the foot relative to the shin as seen in Fig. 1) can be relatively low, so that stable contact of the whole foot with the ground occurs relatively easily and rapidly after heel contact. This joint is predominantly uniaxial, in that it allows only relatively little flexion of the ankle about the longitudinal axis of the foot, a factor which contributes to the stability of the assembly and hence its suitability for limited activity patients.

In dorsi flexion of the ankle, the forward projection 8 engages the rubber buffer 9 for insreased flexion resistance. Normally, the position of the buffer 9 in the keel 1 is adjusted so that engagement with the projection 8 occurs only after flexion of the joint has passed through the neutral position of the bearing 5 from plantar flexion to dorsi flexion.

Heel height, i.e. the height of the heel sole 15 above the ground when the limb is substantially vertical, is adjusted by releasing the clamping of the bearing 5 in the ankle component 7 and

rotating the foot to the required heel height, ensuring that the buffer 9 is not in contact with the projection 8 when the clamping screws are re-tightened. This adjustment can be performed either before or after fitment of the foot assembly to the limb, and since the clamping of the bearing 5 is quite separate from the clamping of the shin tube in the ankle component 7, the foot assembly can be attached and removed without disturbing the heel height setting. The construction of the ankle component 7 which incorporates both the shin tube fastening means and a clamp for a resilient bearing is such that the shin is connected to the foot by a single intermediate component, in contrast to some prior art ankle designs. The assembly of the foot, ankle and shin is thus a relatively quick and simple operation.

It will be seen that the ankle joint is relatively compact and in particular is characterised by the absence of any structural components to the rear of the bearing 5. A relatively large space is therefore available between the bearing 5 and the rear end 20 of the foot for a foam cosmetic covering which is an extension of the shin cosmesis. It will be seen from Fig. 1 that the upper surface of the foot moulding 3 is below the ankle joint axis 21. As a result, the interface between the shin cosmesis and the foot moulding is at a level where the join does not seriously affect the external appearance of the limb in the ankle region. The relatively large permitted thickness of cosmesis behind the ankle joint also improves the external appearance.

Referring now to Fig. 4, a second embodiment of foot assembly is shown which is intended mainly for active patients. The reference numerals in Fig. 4 correspond where appropriate to those in the preceding Figures. As with the first embodiment, the foot assembly comprises a keel 1 and a foot moulding 2 with an upper surface 3 below the axis 21. The upper ankle component 7 has a receptacle 10 which is virtually identical to the receptacle in the first embodiment, and the mating surface 14 is positioned relative to the ankle joint and the sole of the foot such that the first and second embodiments are interchangeable on a limb without necessarily requiring any adjustments to the limb above the ankle. In this embodiment the resilient bearing is in the form of a rubber-filled ball and socket joint 22 having a central ball member 23 fixed to the keel 1, a socket formed by a recess in the ankle component 7 and a clamping cup 24, and a rubber sleeve 25 sandwiched between the socket and the ball member 23. To assemble the joint, the clamping cup 24 and the sleeve 25 are fitted over the ball member 23. The ankle component 7 is then brought down over the sleeve and its lower flange 26 is tightened with four screws 27 onto the flange 28 of the clamping cup to clamp the sleeve and the ball member in the housing. Any flexion of the ankle from the neutral position results in shear deformation of the rubber sleeve 25. Unlike the resilient bearing 5 of the first embodiment the ball and socket joint allows flexion of the ankle about any axis passing through the centre of the joint, and therefore gives the active patient greater freedom of movement. The rubber buffer 9 provides differential flexion resistance in the same manner as in the first embodiment. Heel height adjustment is carried out in a similar manner as described above in relation to the first embodiment.

Two foot assemblies have so far been described which are interchangeable by virtue of the position of the mating surface within the foot assembly. Other foot assemblies with similarly positioned mating surfaces and similar fastening means can be used, for example a foot of the well-known SACH construction with a fixed ankle and a connecting member having a similar receptacle to the receptacles 10 of the above described embodiments.

The SACH foot is used below as an illustration of an alternative mounting interface which allows the interchanging of foot assemblies in accordance with the invention. This interface is more suited to limbs in which the shin member is of a more sophisticated construction, including for example a composite material shin piece which is permanently bonded to an alloy ankle component for reasons of strength and minimum weight. Referring to Fig. 5, a shin piece 29 is tubular in its lower region and is bonded to an internal light alloy ankle component 30 which forms a permanent part of the shin member. The component 30 has a concave part-spherical surface 31 which constitutes the mating surface for engaging an upwardly projecting ball member 32 of a SACH foot. The ball member 32 is clamped into the recess formed by the spherical surface by a releasable clamping ring 33 having a part-spherical inner surface which engages the lower surface of the ball member 32, and a turntable locking ring 34 which has opposite screw threads engaging corresponding threads at the outer surfaces of the components 30 and 33. The ball member 32 is bolted to the keel 35 of a SACH foot. In common with known SACH foot assemblies the foot has a heel cushion 36. It also has a substantially solid ankle; the rubber layer 37 around the ball member 32 is relatively thin and serves to grip the spherical surfaces of the ankle components when the locking ring 34 is tightened. The ball and socket configuration of the joint allows the orientation of the foot to be adjusted.

Should the prosthetist wish to replace the SACh foot assembly of Fig. 5 by a different foot assembly, the locking ring 34 is released, the ball member 32 is separated from the shin, and the replacement foot assembly, having a similar ball member and lower ankle component is offered up to the surface 31. Such a replacement foot assembly is shown in Fig. 6, clamped to the same shin piece 29 and ankle component 30. In this embodiment the ball member 32 is smaller and is enclosed by a much thicker rubber layer or cap 37 to produce a relatively flexible joint. However, it should be noted that the overall diameter of the

ball member and covering layer is substantially the same as in the embodiment of Fig. 5, and that the centre of the ball member is at the same distance from the sole of the foot. The two foot assemblies can therefore be interchanged without altering the length of the shin member. Another aspect of the interchangeability lies in the positioning of the upper surface 38 of the foot moulding. In both embodiments this is the same relative to the ball member and the sole of the foot so that the foot assemblies can be interchanged without modification of the shin cosmesis, this being normally a foam sleeve which abuts the top surface of the foot moulding.

CLAIMS

1. A method of making an artificial leg comprises the steps of:—

(i) providing a shin member of a required length having a lower end portion including a mating surface;

(ii) providing a plurality of interchangeable artificial foot assemblies each of a different kind and each including a connecting member constructed to fit the lower end portion of the shin member and to be removably connectable thereto by releasable fastening means, the connecting member including a mating surface for engaging the shin member mating surface so as to determine the position of the connecting member relative to the shin member;

(iii) selecting any one of the foot assemblies, the selection being independent of the shin member length; and

(iv) mounting the selected foot assembly on the lower end portion of the shin member and securing the foot assembly to the latter by the releasable fastening means.

2. A method according to claim 1 wherein the said foot assembly is selected from a plurality of different foot assemblies in which the position of the connecting member mating surface in each assembly is such that in the assembled leg the distance between the shin member and the sole of the foot in the longitudinal direction of the shin member is substantially constant irrespective of which foot assembly is selected.

3. A method according to claim 1 or claim 2, wherein the connecting member in each of the foot assemblies has a cylindrical receptacle for housing a shin member of circular cross section, the receptacle including an end wall which constitutes the connecting member mating surface and which for each foot assembly is at the same predetermined distance from the sole of the foot assembly.

4. A method according to claim 3, wherein the connecting member in each foot assembly includes a screw operated clamp.

5. A method according to claim 3 or claim 4, wherein for each of the foot assemblies the connecting member is flexibly mounted on a foot

6. A method according to claim 1 or claim 2, wherein the shin member has a concave part-spherical mating surface, and wherein each foot assembly has a connecting member in the form of a ball member having a part-spherical surface, which surface constitutes the connecting member mating surface and which surface, for each foot assembly, is at the same predetermined distance from the sole of the foot.

7. A method according to claim 6 wherein the shin member is clamped to the ball member by a releasable clamping ring which engages a portion of the outer surface of the ball member facing away from the shin member.

8. A method according to any preceding claim further including the step of setting the angle of the foot relative to the connecting member, the connecting member being adjustably mounted in the foot assembly such that the set angle remains undisturbed when the foot assembly is attached to or detached from the shin member.

9. A method according to claim 8, wherein the setting step is a heel height setting step.

10. A method according to any preceding claim, wherein each foot assembly includes a flexible cosmetic foot moulding having an upper surface which, for each foot assembly is at substantially the same distance from the sole of the foot.

11. An artificial leg comprising: (i) a shin member; (ii) a foot assembly removably mounted on a lower end portion of the shin member, the foot assembly being one of a range of foot assemblies each of a different kind but each so constructed that they fit the lower end portion of the shin member, each assembly having a connecting member with a mounting surface which engages the lower end portion of the shin member and which is so positioned in the foot assembly that one foot assembly can be replaced by another of a different kind from within the range without altering the shin member length.

12. A limb prosthesis comprising: (i) a shin component; (ii) a foot assembly including (a) a foot and an upper ankle component, which component is adapted to connect the assembly to the shin component, the assembly including an ankle joint permitting plantar and dorsi flexion of the foot about an ankle joint axis, and (b) elastic coupling means between the foot and the upper ankle component to resist the said flexion, the elastic rate of the coupling means for dorsi flexion being different from its elastic rate for plantar flexion, the coupling means including one or more elastic members none of which have their major part to the rear of the ankle joint axis; and (iii) a flexible cosmetic shin covering surrounding the shin component and at least the upper ankle component of the said assembly, which covering extends below the ankle joint axis and occupies the space between the upper ankle component and the foot.

13. A method of making an artificial leg substantially as herein described with reference to the drawings.

14. An artificial leg constructed and arranged substantially as herein described and shown in the drawings.

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